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Transport Protocols and Applications for Internet Use in Space

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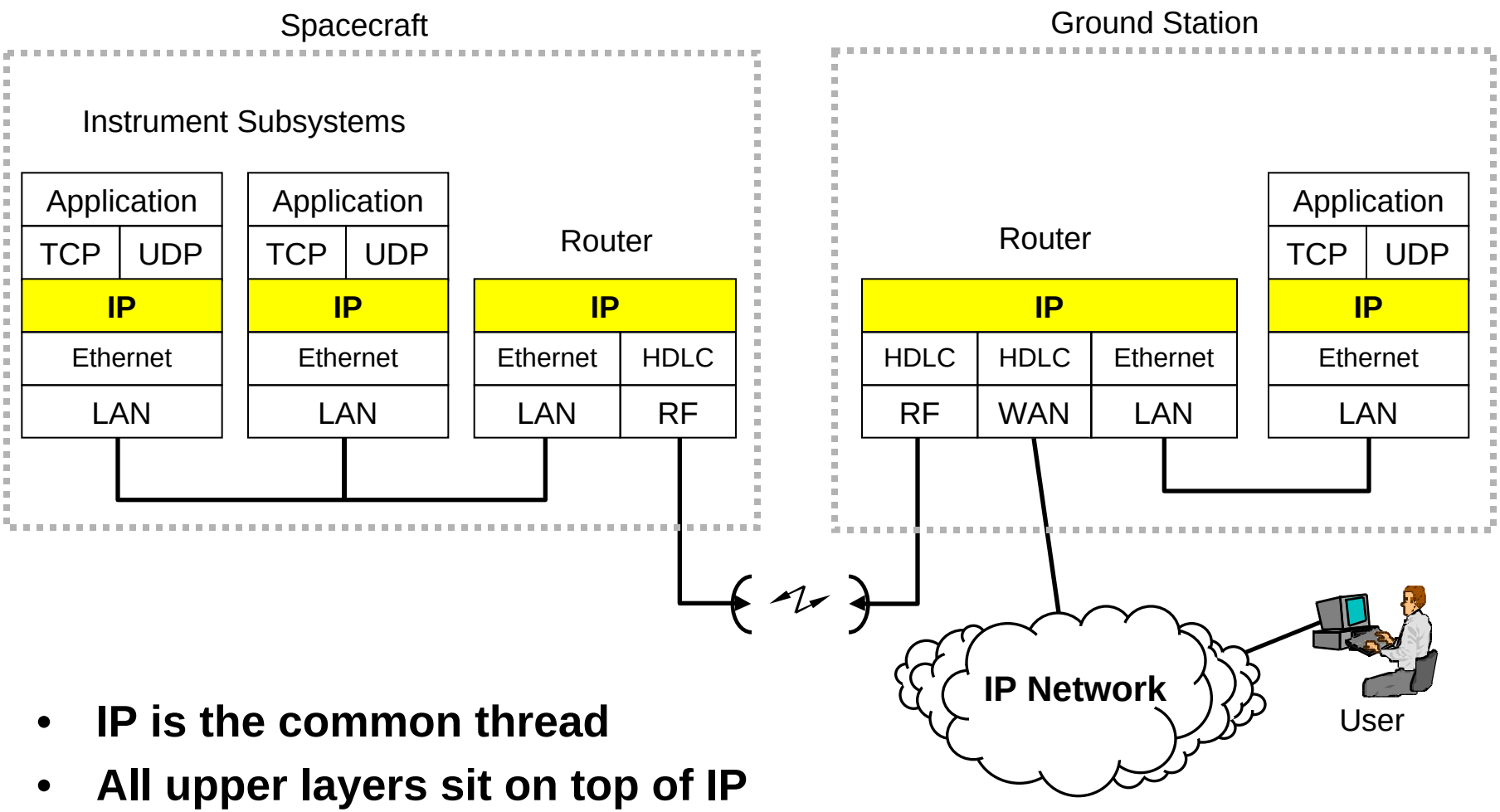
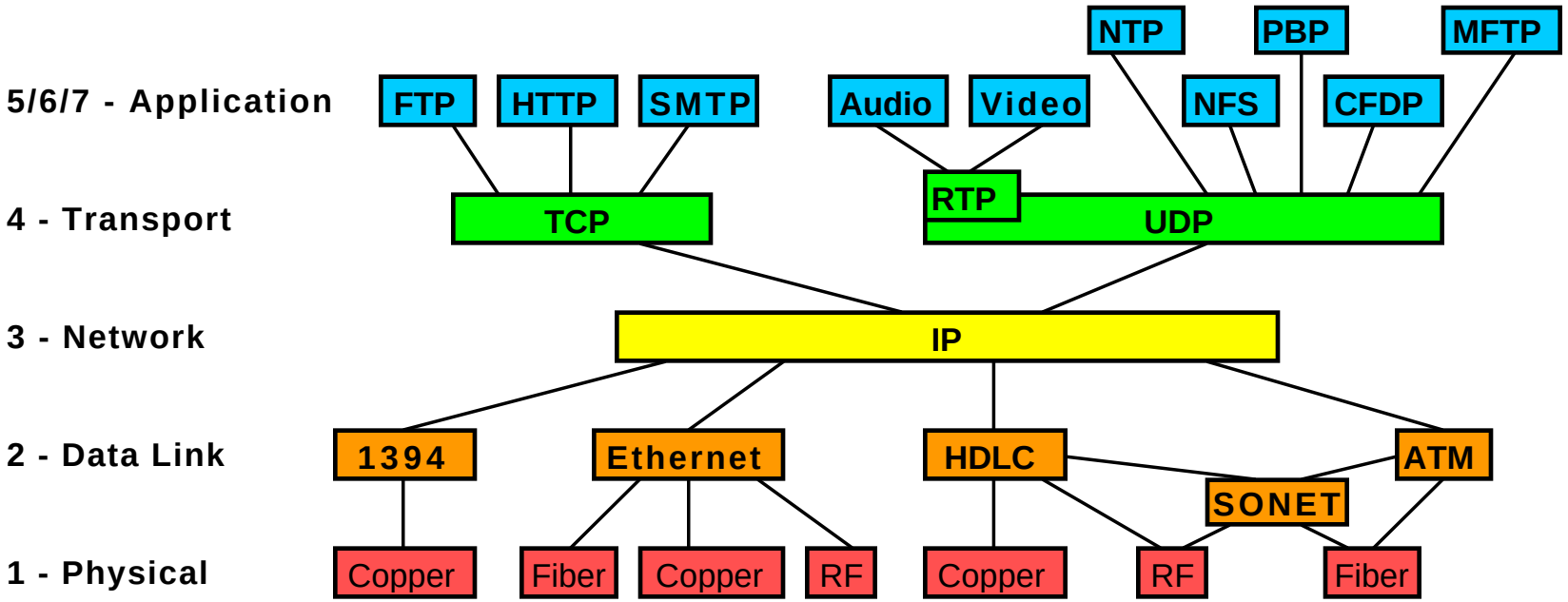
End-to-End IP Network Concept



- **IP is the common thread**
- **All upper layers sit on top of IP**

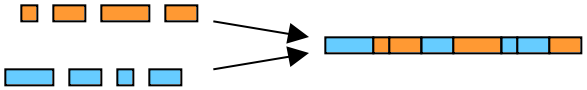
Layered Model



- OSI 7 layer model
- IP is not TCP!
- Paper is on top two layers

Transport layer

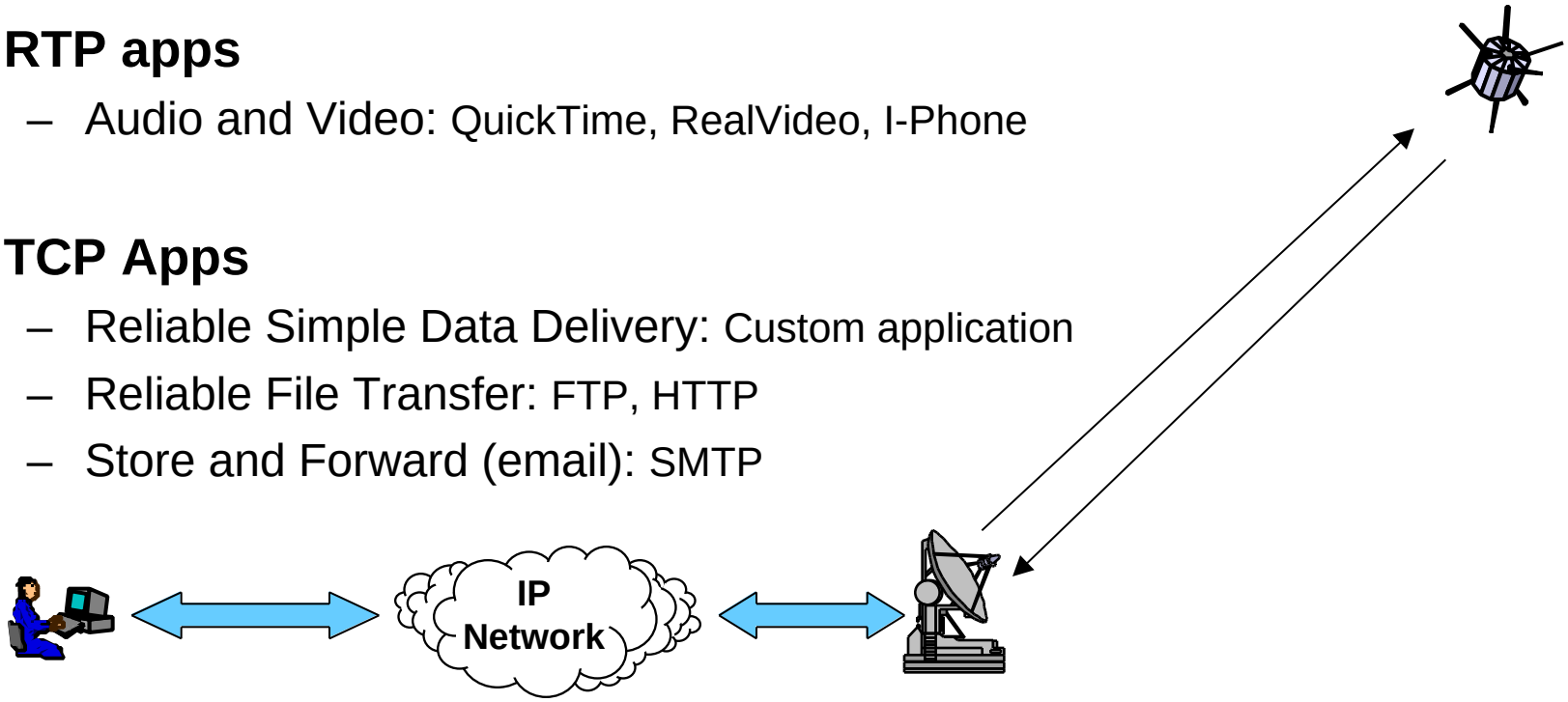
- **Transport layer provides multiplexing**



- **Three main transport layer protocols on the Internet**
  - UDP - User Datagram Protocol (RFC-768)
    - Provides Multiplexing and error detection (checksum)
    - Atomic packet delivery
    - Delivery and delivery order not guaranteed
  - RTP - Real Time Protocol (RFC-1889)
    - Built “on top of” UDP
    - Adds sequence numbering, timestamping, and delivery monitoring
  - TCP - Transmission Control Protocol (RFC-793)
    - Provides multiplexing, flow control, sequencing, error detection, and automatic retransmission
    - Guaranteed in-order delivery
    - Provides a reliable “byte pipe” from sender to receiver.

Application Layer

- **UDP apps**
  - Simple Data Delivery: Custom application
  - Reliable File Transfer: PBP, MDP, MFTP, CFDP, NFS, TFTP
  - Time Synchronization: NTP
- **RTP apps**
  - Audio and Video: QuickTime, RealVideo, I-Phone
- **TCP Apps**
  - Reliable Simple Data Delivery: Custom application
  - Reliable File Transfer: FTP, HTTP
  - Store and Forward (email): SMTP



Space vs Terrestrial Issues

- **Don't Space Links Have Long Delay?**
  - UDP is delay insensitive. Will work to Pluto!
  - LEO is close! 4 - 32 ms Round Trip Time.
  - TCP has been used out to Geosync at over 500 Mbits/sec

- **Aren't Space Links too Noisy for IP?**
  - Only TCP throughput affected by noise. IP & UDP are not.
  - FEC used to improve space link BER. 10^{-5} is spec, 10^{-7} is typical.
  - Uncorrected Telephone lines have a BER of 10^{-5}!
  - ECN, SACK, TCP/PEACH are coming

More Space vs Terrestrial Issues

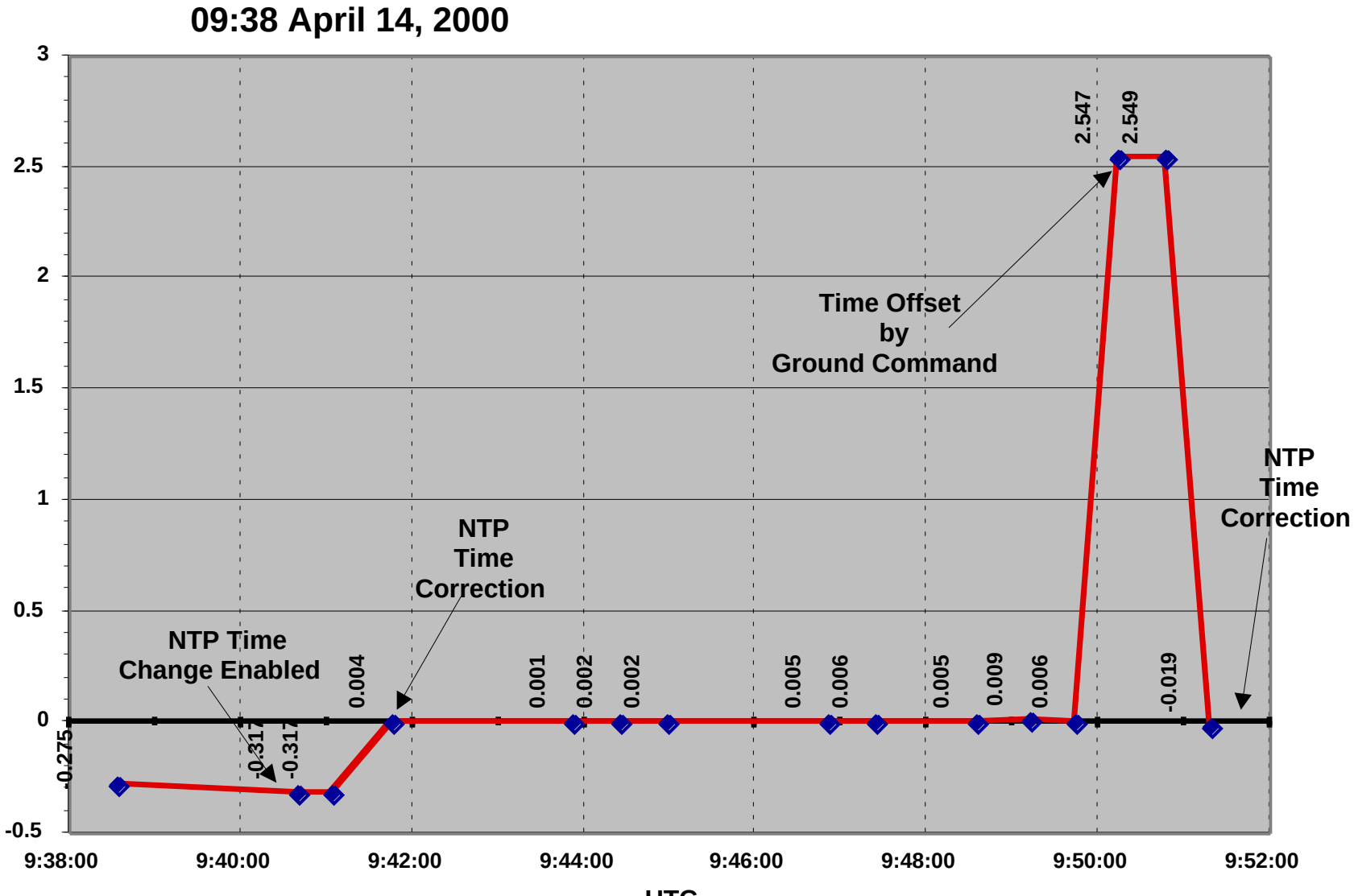
- **Don't Spacecraft Have Constrained Power, CPU, & Bandwidth?**
  - Compare to an Internet-ready cell phone.
  - New CPUs (StrongArm, PowerPC 750) are ready to fly.
- **Isn't Spacecraft Connectivity too Intermittent and too Variable for IP?**
  - Just like laptop computers, cell phones, automobiles
  - Mobile-IP, DHCP
- **Spacecraft Have Huge Forward/Return Path Asymmetry**
  - Driven by convention, not physics.
  - STDN compatible receivers limited to 4 kbps uplink
  - TDRSS can do 2 mbps symmetric

IP Operations Scenarios

- **Real time telemetry**
  - Unidirectional - UDP
  - Reliable - TCP
- **Reliably Downlink Recorded Science & Engineering Data**
  - Short Delay - FTP
  - Long Delay - PBP / MDP / CFDP
  - Store & Forward - SMTP
- **Onboard Clock Synchronization**
  - Synchronization and drift mitigation - NTP
- **Commanding**
  - Store & Forward - SMTP
  - Reliable Realtime - TCP
  - Blind Realtime - UDP

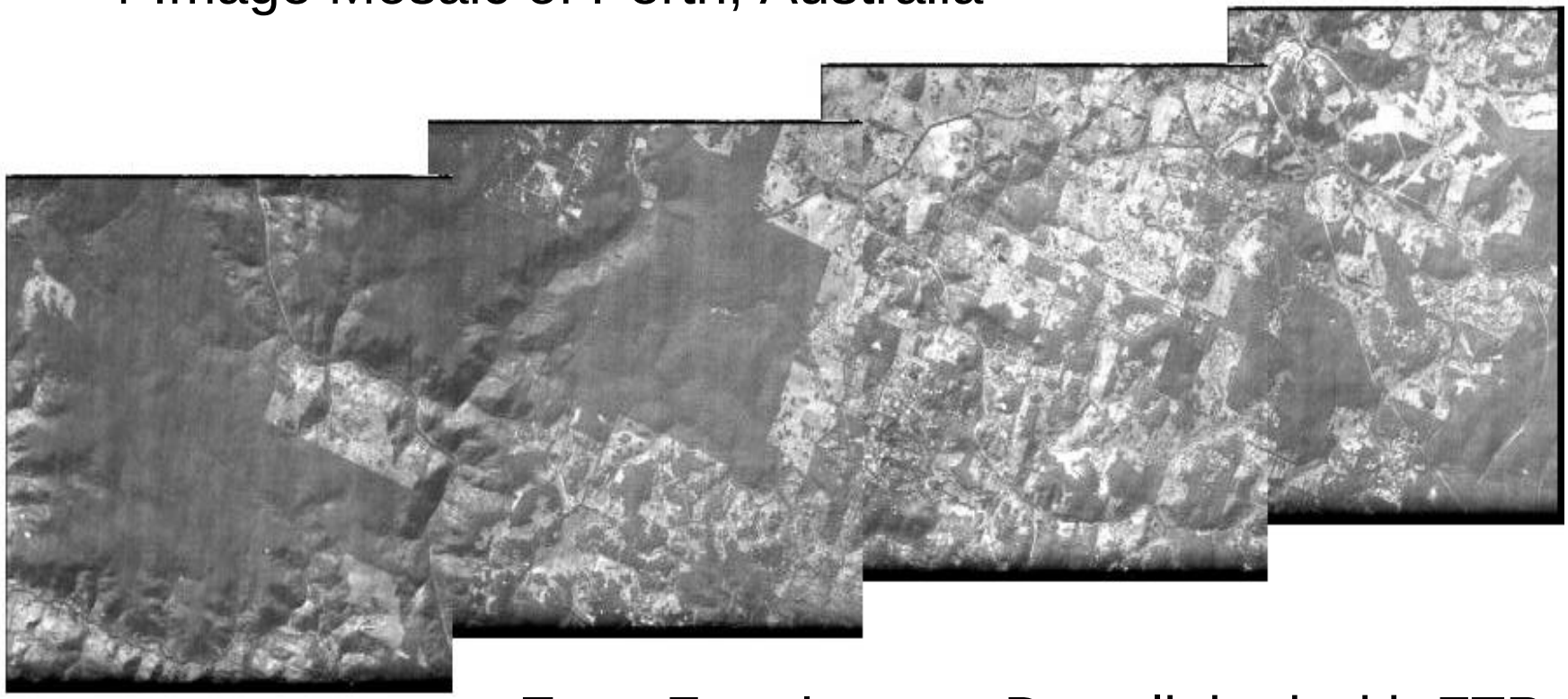
On-Orbit Tests With UoSat-12

Spacecraft Clock Sync via NTP



Instrument Data Delivery via FTP

4-Image Mosaic of Perth, Australia

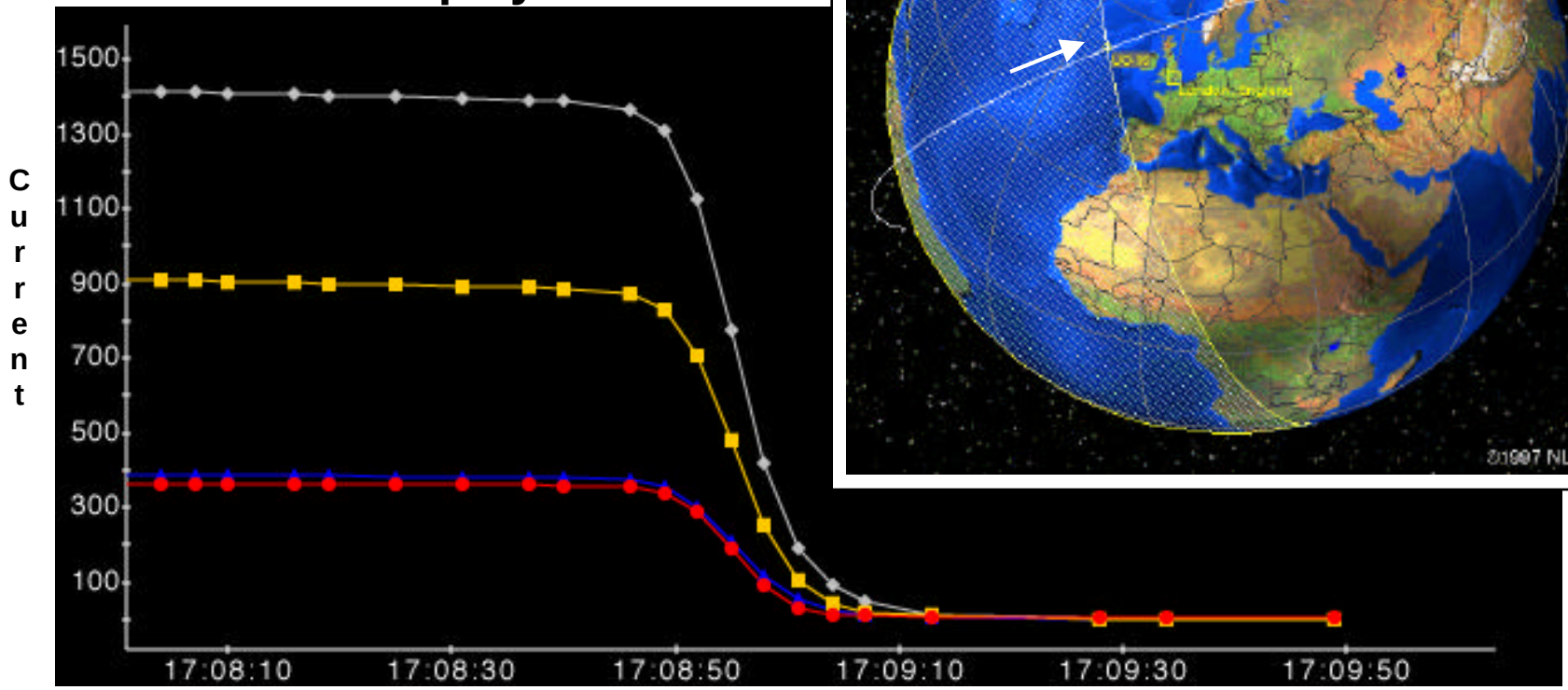


Error-Free Images Downlinked with FTP
June 7, 2000

Real-Time Telemetry via UDP

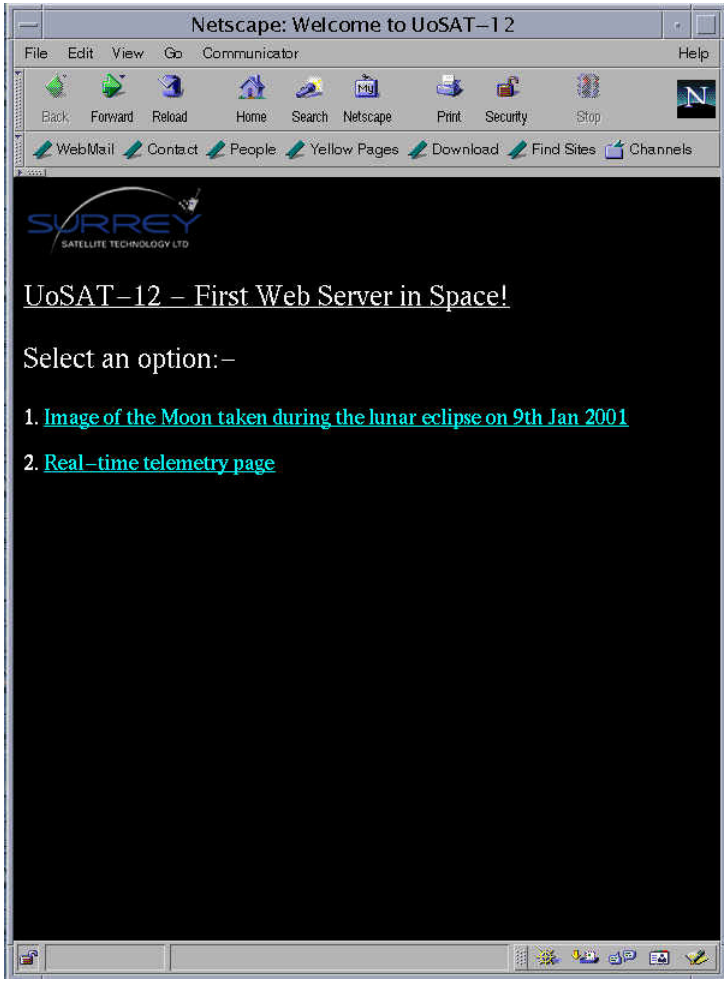
UoSat-12 Solar Panel Currents
As Spacecraft Goes Into Eclipse
December 13, 2000

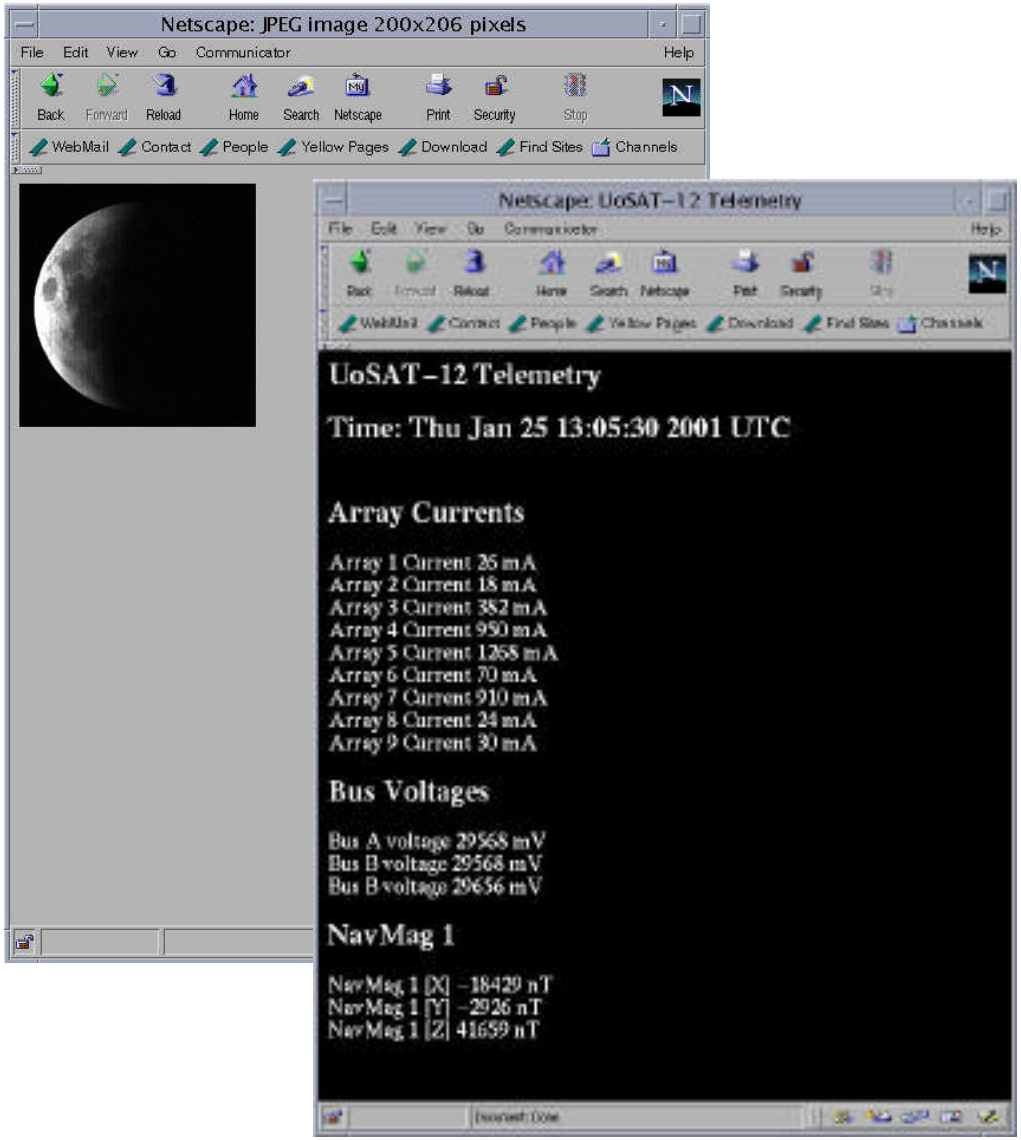
ITOS Display



Telemetry and Stored Data via HTTP

January 25, 2001





Future

- **Ground-based Flatsat Testbed**
  - UDP-based reliable file transfer
  - Mobile IP
  - Mobile Router
  - IPSEC, VPN

- **Flight Validations**
  - UDP-based reliable file transfer
  - Blind Commanding
  - Mobile IP
  - SMTP-based Store & Forward

http://ipinspace.gsfc.nasa.gov/